Special Focus, Retina, Original Article

Jet stream related iatrogenic retinal breaks during vitreo-retinal surgery

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Purpose: To evaluate the causes of jet stream injury (JSI)-related iatrogenic retinal breaks (IRBs) during vitreoretinal surgery (VRS). **Methods:** The precise surgical environment, which includes the indication and type of surgical procedure, retina status, details of instrumentation and fluidic parameters, and characteristics of the jet responsible for the IRB, was noted from case records. The nature of IRB and its healing and impact on anatomical and visual outcomes were analyzed. **Results:** Five eyes of five patients with complete documentation of both the JSI and the IRB were included. Two cases were operated for macular hole, and one each for vitreous hemorrhage, retinal detachment, and endophthalmitis. One case had infusion-fluid-related JSI, while four developed it because of injection of surgical adjuncts (drugs, PFCL, and dye). JSI developed in two cases when the vitreous cavity was filled with fluid, while it was air-filled in three cases. In four cases, the fluid migrated into subretinal space, necessitating further maneuvers following which the breaks healed, but were directly responsible for vision loss in two cases. **Conclusion:** JSI related IRBs are rare but may be directly responsible for vision loss if they impact the macula. The balance between jet stream velocity, its distance from the retinal surface, the intervening media (vitreous cavity), and retinal health play an important role. It can occur because of both infusion as well as injection jets. Precautions must be taken in cases vulnerable to complications with suggested modifications in the surgical technique.

Access this article online
Website: www.ijo.in
DOI: 10.4103/ijo.IJO_1918_21
Quick Response Code:

Key words: Iatrogenic retinal breaks, infusion fluid-related retinal injury, jet stream injury, vitreoretinal surgery

Jet stream injury (JSI) to the retina is a rare but serious complication of vitreoretinal surgery (VRS). Typically, it manifests following the introduction of a high-velocity fluid jet inside the vitreous cavity. It can result in iatrogenic retinal breaks (IRBs), subsequent subretinal migration of fluid or surgical adjuncts, and potentially a retinal detachment too. JSIs warrant unplanned surgical maneuvers and can be challenging for the operating surgeon to manage.[1] Due to the high likelihood of posterior pole injuries, visual outcomes may be severely impacted by JSI.

Various reasons have been considered for JSI, including mechanical insult by the infusion jet. Current vitrectomy units have an inbuilt intraocular pressure (IOP) compensating system and respond in real time to the IOP fluctuations. These IOP adjustments are made by increasing the infusion flow rapidly in response to ocular hypotony that may have occurred during surgery.[1,2] Previous reports have identified air–fluid exchange in a non-valved vitrectomy port system,[3] higher infusion pressure,[3,4] and compromised neural retina (that cannot withstand the mechanical insult consequent to a jet stream) as the risk factors for jet stream-related IRB.[5] JSI-related IRBs induced by infusion jets typically occur in locales diagonally opposite to the infusion cannula.[3]

Being rare, the literature on JSI is very scant. The available reports have understandably few numbers and are also limited by low evidence regarding the precise timing of the JSI and the course of healing of the IRB.[3,5] Furthermore, most documented reports have considered only infusion-flow-related jets as the cause of JSI, and injection jet-related injuries have not been discussed. The objective of this case series is to explore and analyze all possible causes of JSI regardless of the surgical indication and ascertain its effects on outcomes. We also discuss the necessary precautionary measures that can be taken during vital surgical steps to avoid JSI related IRBs.

Methods

This is a retrospective review of records of cases where JSI had been noted by surgeons. The study protocol has been reviewed by the institute's review board, and data collection was started

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Received: 17-Jul-2021 Revision: 09-Sep-2021
Accepted: 20-Oct-2021 Published: 25-Feb-2022

Cite this article as: Belenje A, Takkar B, Agarwal K, Tyagi M, Aggarwal V, Padhi TR, *et al*. Jet stream related iatrogenic retinal breaks during vitreo-retinal surgery. Indian J Ophthalmol 2022;70:902-7.

after due approval by the local ethics committee (Ethics number: LEC-BHR-R-09-20-494). All study procedures are in accordance with the tenets of the declaration of Helsinki and its later amendments. Retrospective data collection was done across the participating VRS centers. Cases where JSI had been established during surgery were included. All surgeries had been performed using a single vitrectomy system that involved the use of pressurized infusion and inbuilt IOP compensation (Constellation vision system, Alcon, Texas). Cases where documentation was incomplete, where the JSI was speculative, or where the IRB could not be attributed directly to a particular surgical step were excluded.

The records were evaluated for the surgical environment preceding the occurrence of JSI along with details of the surgical step being performed [Table 1]. To ascertain the cause of JSI, data collection included the surgical indication, infusion pressure, gauge of instruments, type of cannula (valved vs. non-valved), instrument being used at the time of JSI with its location in the vitreous cavity, the content of the vitreous cavity, and the fluid responsible for the mechanical injury. The location of the injection cannula during the JSI was judged using a combination of surgical video, surgery notes, and the surgeon's response to leading questions. Location of the cannula within the posterior third of the vitreous cavity was considered as posterior. To ascertain the impact of JSI on outcomes, we also evaluated variables related to the IRB and its management [Table 2]. This data included the location of the IRB, unplanned surgical maneuvers performed to tackle the consequences of the injury (like retinal detachment and subretinal migration of the agent), the tamponade agent used to settle the retina, and the final outcomes during follow up in terms of visual acuity and healing of the IRB.

The main outcome measure was to ascertain the risk factors of JSI, while the impact of the JSI on surgical outcomes was evaluated secondarily. In total, five cases met the study criteria and were included in the evaluation. This case series involves only a descriptive analysis of the frequency of events.

Results

The surgical indications, steps, and causes of JSI have been summarized in Table 1, and the management and follow-up have been presented in Table 2.

Case 1: An 18-year-old girl was diagnosed with endogenous endophthalmitis in her right eye. She had been operated before for minimal core vitrectomy with vitreous biopsy and intraocular antibiotic (IOAB) injection. She underwent a repeat 23-G pars plana vitrectomy (PPV) through a non-valved cannula for persisting vitreous exudates. The IOP was maintained at 30 mm Hg with an aspiration rate of 100–400 mm Hg. After clearing the vitreous exudates, the optic disc was visible and the retina looked ischemic and atrophic with sclerosed vessels. Fluid–air exchange (FAE) was done. Intraocular antibiotic (IOAB) injection was given with a 30-G needle in the temporal quadrant with 1/3rd of the needle inside and needle tip directed toward the posterior pole. A small IRB was noted in the inferonasal retina near the arcades with a small pocket of subretinal fluid with drug precipitates. The break was cauterized and subretinal fluid drained, followed by laser around the break and silicone oil injection. Subsequently, the patient developed an epiretinal membrane over the posterior pole and mid periphery for which she underwent repeat surgery. Her final visual acuity was 20/400 at 6 months follow-up with oil *in situ*.

Case 2: A 70-year-old lady was diagnosed with left-eye full-thickness idiopathic macular hole and was planned for 25-G PPV through a valved cannula with internal limiting membrane peeling (ILMP) and gas tamponade. IOP-compensated infusion was maintained at 30 mm Hg with an aspiration rate of 300–400 mm Hg. After completing central vitrectomy, posterior vitreous detachment (PVD) was induced with suction of cutter tip and peripheral vitrectomy was completed. FAE was done, and the internal limiting membrane (ILM) was stained with 0.05% brilliant blue dye for 20 s. Infusion was then switched on and air was aspirated actively. During this step, a sudden jet of infusion was released from the cannula placed in the inferotemporal quadrant. It hit the superior-nasal retina, causing a break along the arcade with subretinal fluid (SRF) surrounding the break [Fig. 1]. ILMP was completed and FAE was done with endolaser around the break. Gas was injected and the patient was advised strict prone position. However, the macular hole did not close and the patient underwent a repeat fluid gas exchange (FGE). The macular hole closed following the second surgery and the patient attained a corrected visual acuity of 20/160 at 3 months.

Table 1: Surgical environment preceding the JSI related IRB

Surgical indication	Infusion IOP (mm Hg)	Cavity content	Instrument gauge	Valved cannulas	Surgical step	Location of cannula	Inadvertent injection of the drug causing JSI	Subretinal migration	Surgeon's experience
Case 1 Endophthalmitis	30	Air	30 G	No	Antibiotic injection	anterior	antibiotic	Yes	12 years
Case 2 Macular hole	30	Air	25 G	Yes	Air-fluid exchange During dye extraction	anterior	Infusion fluid	Yes	2 years
Case 3 Macular hole	30	Fluid	25 G	No	Dye injection	posterior	Vital dye	No	6 years
Case 4 Vitreous hemorrhage	NA	Air	26 G	No	Inadvertent injection of fluid instead of gas	anterior	Dexamethasone	Yes	8 years
Case 5 Retinal detachment	30	Fluid	23 G	No	Heavy liquid injection to settle retina	posterior	PFCL	Yes	6 years

IOP: intraocular pressure, JSI: Jet stream injury, Iatrogenic break, PFCL: perfluorocarbon liquid

Case 3: A 60-year-old man was diagnosed with left-eye full-thickness idiopathic macular hole and was planned for a 25-G PPV through a non-valved cannula with ILMP and gas tamponade. IOP was maintained at 30 mm Hg with an aspiration rate of 300–400 mm Hg. After completing central vitrectomy, PVD was induced with suction of cutter tip and the vitrectomy was completed. Brilliant blue dye was used to stain the ILM through the fluid-filled cavity. The ILM was not stained uniformly, and hence re-staining of ILM was performed with the tip of the flute cannula in the posterior vitreous cavity. A small iatrogenic break was created temporal to fovea right in line with the injection jet [Fig. 2]. No retinal detachment was noted. ILMP was completed, and FAE followed by FGE was done. Further, 12% perfluoropropane (C3F8) gas was used. At the postoperative visit of 4 months, the BCVA was 20/100 with closure of both macular holes. Optical coherence tomography (OCT) passing through the IRB site showed damage to the outer retinal layers [Fig. 3].

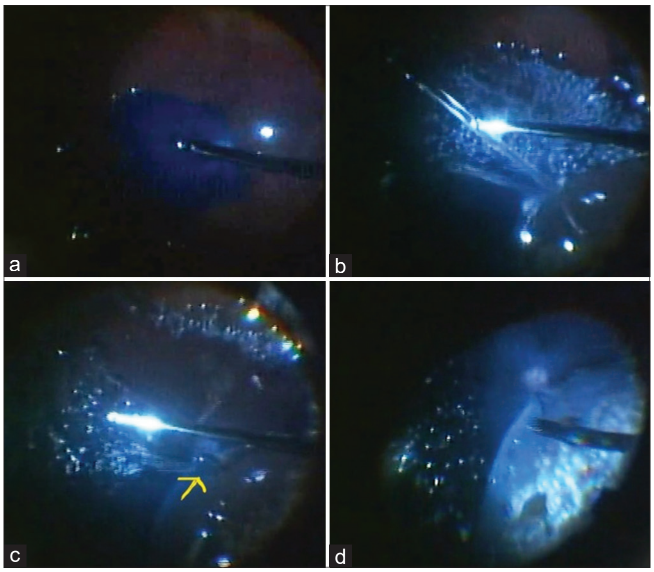

Figure 1: Intraoperative findings in case 2. (a) Air–fluid exchange is being performed while dye has already been injected. (b) Sudden jet of infusion released from the cannula placed in the inferotemporal quadrant hits the superior-nasal retina. (c) Fluid jet created a retinal break due to impact (arrow) while air–fluid exchange is continuing. (d) Subretinal fluid (SRF) and localized retinal detachment around the break occurred almost immediately

Case 4: A 48-year-old gentleman was diagnosed with pre-senile cataract and non-resolving vitreous hemorrhage due to proliferative diabetic retinopathy in the left eye. He underwent phacoemulsification with intraocular lens implantation, combined with 25-G PPV through a non-valved cannula. The IOP was maintained at 30 mm Hg with an aspiration rate of 300–400 mm Hg. FAE was done and the cannula was removed. Instead of injecting sulfur hexafluoride (SF_6) gas, the operating surgeon inadvertently injected 2 ml fluid containing the subconjunctival preparation of dexamethasone. Realizing the mistake, the cannulas were reinserted immediately when an IRB was noted around 2-disc diameter temporal to macula with surrounding SRF [Fig. 4].

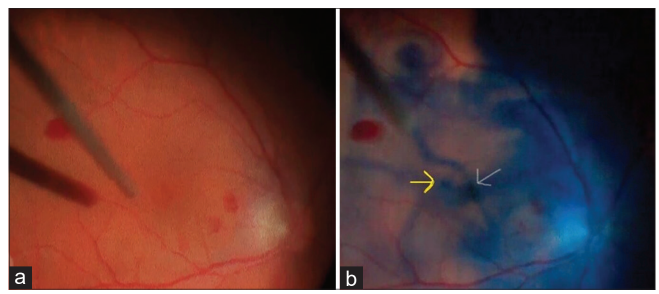

Figure 2: Intraoperative findings in case 3. (a) Re-staining of ILM was attempted with the tip of the injector in the posterior vitreous cavity while the vitreous cavity was fluid-filled. Pre-existing macular hole is present along with superficial retinal hemorrhages. (b) A small iatrogenic break (yellow arrow) was created temporal to the preoperative macular hole (white arrow) immediately after dye injection right in line with the injection jet

Table 2: Details of IRB due to JSI and management

Location	RD	Tamponade required	Unplanned surgical maneuvers necessitated	Final visual acuity and period of follow up	Healing of IRB
Case 1 Inferonasal	yes	Silicone oil	Endolaser to break site and SOI	20/400 at 6 months follow-up	RD settled, break closed well
Case 2 Superior-nasal along the arcade	yes	C3F8 gas	Extensive vitreous cortex dissection followed by settling of RD, endolaser to break site and gas tamponade	20/160 at 3 months follow-up	RD settled, break closed well.
Case 3 Juxta-foveal	no	C3F8 gas	none	20/100 at 4 months follow-up	Healed with pigmentation and photoreceptor damage on OCT
Case 4 3 mm temporal to fovea	yes	SF6 gas	Reinsertion of cannula, air-fluid exchange, then repeat fluid-air-gas exchange	20/40 at 6 months follow-up	Break healed well
Case 5 Foveal hole	Pre -existing, but PFCL migration below macula	Silicone oil	ILMP with active aspiration of PFCL with 38G cannula and silicone oil exchange.	20/200 at 4 months follow-up	Macular hole closed

JSI: jet stream injury, IRB: iatrogenic break, SOI: silicone oil injection, PFCL: perfluorocarbon liquid, RD: retinal detachment, OCT: optical coherence tomography, ILMP: internal limiting membrane peeling

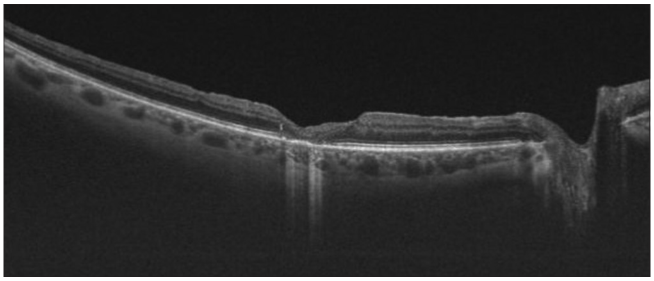

Figure 3: Postoperative optical coherence tomography of case 3 at 4 months passing through the iatrogenic break (IRB) site showed photoreceptor damage though both holes have closed

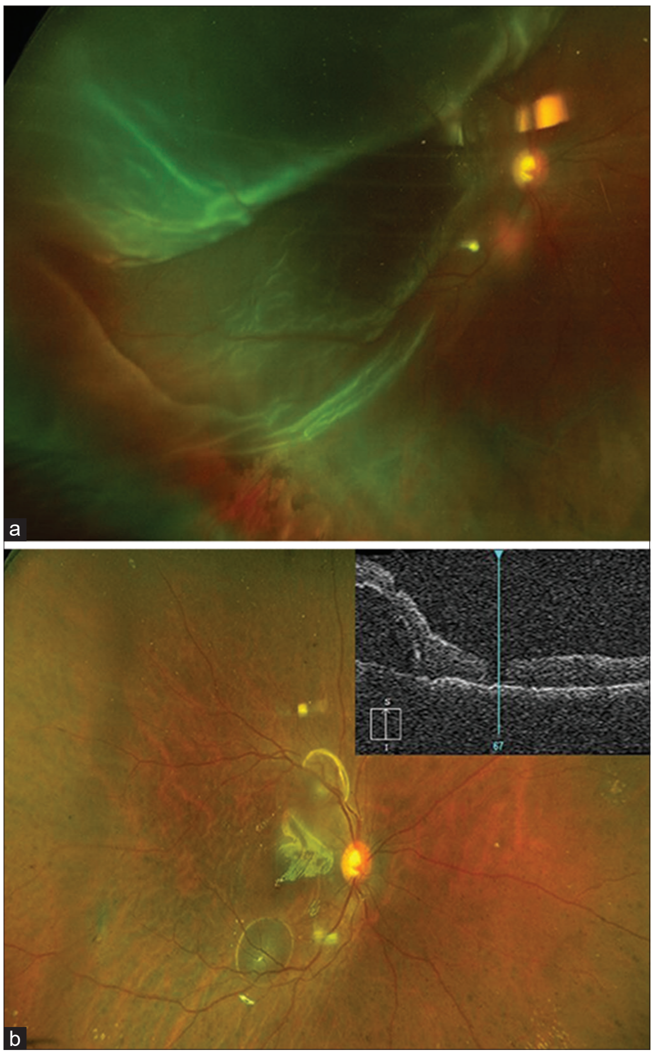

Figure 5: Findings of case 5. (a) Right eye rhegmatogenous retinal detachment preoperatively. (b) Postoperative fundus photograph showing retained PFCL bubbles in the extrafoveal subretinal space of right eye (outset), and optical coherence tomography vertical scan showing a small full-thickness macular hole and also subretinal migration of PFCL bubble (inset)

The infusion was switched on and all the drug was washed off [Fig. 4]. FAE was done, SRF was aspirated, and pure SF6 gas tamponade was used as planned. The patient did well postoperatively, and his BCVA was 20/40 at 6 months.

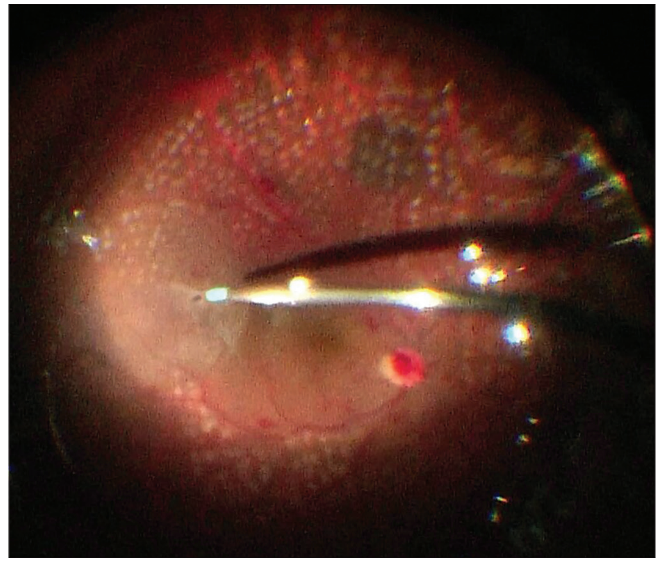

Figure 4: Iatrogenic retinal break in case 4 formed around 2-disc diameter temporal to macula with surrounding SRF. A fluid–air exchange is being performed to aspirate the SRF

Case 5: A 43-year-old gentleman was diagnosed with right-eye rhegmatogenous retinal detachment with a giant retinal tear in the superior-temporal quadrant [Fig. 5a]. The patient had undergone surgical removal of intraocular foreign body with implantation of an intraocular lens in the same eye 6 years ago. He underwent 23-G PPV in the right eye with non-valved cannulas. PVD was already induced in this case, and peripheral vitrectomy was completed. IOP was maintained at 30 mm Hg with a suction of 300–400 mm Hg during the surgery. While injecting perfluorocarbon liquid (PFCL) with the tip of the cannula in the posterior vitreous cavity, the surgeon noted peri foveal hemorrhages and migration of a small bubble of PFCL subfoveally. The patient had developed a small macular hole during JSI that occurred during PFCL injection. The procedure was completed, a subsequent endolaser was done, and silicone oil was injected. The small macular hole was confirmed during postoperative evaluation using OCT [Fig. 5b] along with the presence of a subretinal PFCL bubble in the extrafoveal region. The patient underwent a second surgery later when ILMP was done and PFCL bubbles were aspirated using a 38-G cannula along with a silicone oil exchange. The patient attained a BCVA of 20/200 and an attached retina with closed macular hole at 2 months of follow-up. He was planned for subsequent oil removal.

Discussion

IRB is a serious complication of VRS, and missing it can lead to failure of retinal surgery and vision loss.[6] The typically vulnerable cases include tractional retinal detachment without PVD and macular hole. The frequency of IRBs is close to 10% of the operated cases overall.[7] Such complications necessitate further maneuvers and sometimes second procedures too, potentially thwarting good visual outcomes.[7] In general, advances in VRS have decreased the frequency of IRBs.[8] JSI-related IRBs are extremely rare as discussed before, and ironically have been linked to advances in VRS in at least some of the cases. As seen in our series too, they can occur due to sudden IOP compensation during minimally invasive VRS. One of the objectives of the current series was to critically identify the actual events where JSI-related IRBs were happening. We found JSI-related IRBs to occur in a myriad of retinal conditions [Table 1]. They were more common in cases where the vitreous cavity was filled with air prior and forceful injection of surgical adjunct/infusion fluid was done from the scleral site far away from the retina (cases 1, 2, and 4). In contrast, we also found a posteriorly delivered injection through a fluid-filled vitreous cavity to be sufficient enough to cause an IRB too (cases 3 and 5). Subretinal migration of fluid/adjunct was seen in most cases, causing a localized retinal detachment [Table 1].

In the case series by Rishi *et al*.,[3] JSI-related IRBs were found in four cases operated for macular holes while being managed with 25-G non-valved cannulas. In all of their cases, the injury was related to infusion jets during air–fluid exchange. Bilgin *et al*.[5] reported three cases where JSI-related IRBs occurred diagonally opposite to the infusion cannula in the nasal midperiphery. Surgery was performed in one of their cases for vitreous hemorrhage, while silicone oil removal was being performed in the other two cases. Bilgin *et al*.[5] concluded that uncontrolled rapid air–fluid exchange and excessive scleral indentation during surgery can cause rebound hypotony, leading to sudden compensation of IOP by the vitrectomy machine leading to JSI-related IRBs. However, one of their cases had developed multiple retinal breaks during the course of management. They recommended a careful and controlled air–fluid exchange during vitrectomy using a 25-G valved cannula while keeping the infusion inflow rate at a low parameter limit (<4 ml/min).[3,5] In our case series, we encountered a "typical" JSI (case 2) while using a valved cannula. Additionally, we saw multiple cases where JSI-related IRBs occurred due to injection of a surgical adjunct [Table 1].

The literature lacks well-documented case series for injection-related JSI. A single case was noted by Barman *et al*.,[9] where triamcinolone acetonide (TA) was injected to assist complete vitrectomy. When the same cannula was used to inject brilliant blue dye for staining ILM, a small plug of crystals of TA came out forcefully and hit the perifoveal retina, causing an IRB. That IRB had healed with scarring at 2 months.[9] We noted four cases of injection-related JSI where IRBs occurred. All these cases had the IRB at the posterior pole, with two right near the fovea or involving it. The visual implications of such an injury in relation to macular or paramacular breaks are obvious. Table 2 shows the relatively poor visual outcomes, though some of these cases had more reasons other than the IRB to cause poor vision (cases 1 and 5). Case 3 also showed visible irreversible damage to the outer retina of the parafoveal area during healing of the IRB as seen on OCT [Fig. 3]. In contrast, in cases of infusion-related JSI reported by Bilgin *et al*., BCVA was better than 20/200 in all cases, while Rishi *et al*. noted it to be better than 20/40 in 3/4 cases.[3,5]

PFCL (case 5), vital dye (case 3), antibiotic (case 1), and dexamethasone (case 4) are commonly injected into the vitreous cavity for various indications. Thus, all the adjuncts used in the four cases of injection jet-related IRBs noted by us are generally considered to be safe.[10] Thus, rather than the adjunct, we believe that it was the surgical technique that was responsible for the IRB. Retinal breaks and retinal detachment are highly uncommon after intravitreal injections in vitreous-filled eyes, and the frequency is said to be less than 0.1%. The mechanisms for retinal breaks in that situation are considered to be much different from JSI and involve traction. Furthermore, the vitreous acts as a cushion and counteracts the pressure effects of the injections in those eyes.[11] Routinely given intravitreal injections after PPV for any indication are also considered to be safe in the perspective of IRBs, even in the case of triamcinolone, which is crystal-based.[12] The difference between these office procedures and VRS related injections in our series is two-pronged. First, in cases 1 and 4, the eye was air-filled. Thus, rather than having a dissolution effect, the injection proved to be a powerful jet in these cases, whereas in cases 3 and 5, though the vitreous cavity was full of fluid like any post-vitrectomy eye, the injection was delivered very close to the retina with the cannula tip being deep in the vitreous cavity. In contrast, in routine intravitreal injections, the needle does not reach close to the retina. Furthermore, most of our five cases may have been prone to retinal breaks, as is well known for macular holes, endophthalmitis (due to atrophy), and proliferative diabetic retinopathy (due to edema).

Limitations and strengths

Though this is the largest series of JSI-related IRBs reported, this series is limited by its numbers. Another limitation is that the operating surgeons were different in these cases with varying years of surgical experience [Table 1]. However, this also shows that JSI is not a surgeon- or an indication-specific phenomenon, as noted by Rishi *et al*.[3] Fluidics and air-jet-related injury has also been linked to visual field deficits corresponding to dehydration injury of the nasal retina during surgery for macular hole.[13] Interestingly, some authors have also noted the development of "white areas" in the retina due to air jets at high pressures, which later manifested full-thickness retinal breaks in the postoperative period, causing retinal detachment.[14] These phenomena, and the cases reported by us, Bilgin *et al*.,[5] and Rishi *et al*.,[3] clearly indicate the shrouded nature of JSI-related IRBs. In the opinion of the authors, adoption of the following simple methods can help in reducing the incidence of JSI-related IRBs and their detrimental impact on visual outcomes:

1. Careful and passive air–fluid exchange performed slowly.
2. Maintaining stable and low IOP during air–fluid exchange.
3. Injecting adjuncts slowly over a "puddle of fluid" if under air and always directing fluid currents away from weak areas and macula.
4. While under air or fluid, breaking the jet stream by usage of a second instrument like the endo-illuminator.
5. Preferable injection of fluid adjuncts from the anterior vitreous cavity while pointing injection tip away from the macula.

Conclusion

To summarize, JSI-related IRBs are rare but can have a detrimental impact on outcomes. We have explicitly noted the peri-IRB events and have shown that they can occur because of both infusion as well as injection-related insults. Minute modifications of the surgical technique while handling air–fluid exchange and injection of surgical adjuncts may reduce these events.

Financial support and sponsorship

a) AB, BT, KMA, TRP, MT, RN: Hyderabad Eye Research Foundation, Hyderabad, India
b) BT and RN: DBT Wellcome Trust India Alliance Clinical Research Centre Grant awarded to IHOPE [grant number IA/CRC/19/1/610010].

Conflicts of interest

There are no conflicts of interest.

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